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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

HIGH SPEED
BALL BEARING
LUBRICATION

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

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A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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High Speed Ball Bearing Lubrication

Ages before science had discovered that the speed of sound and light could be measured, prehistoric man had learned that his life and livelihood could depend upon speed. The faster he could drive an arrow the more chance he had of bringing down running animals—his basic food supply. The faster he himself could run, the more easily could he outstrip his enemies and live to fight another day. Speed entered into the mechanical stage when war chariots were equipped with wheels which turned faster on their axles when greased. So lubrication early became a counterpart of speed but nobody wondered why.

Speed has been an objective dating back to antiquity. Down through the ages, it has played an important part in the shaping of history and the development of our modern civilization. The war chariots of the Egyptians; the speedy Roman galleys at the Battle of Actium; the Marathon Run; even the speed of the arrows from the English long-bows, all, along with many other historical events indicate how our destiny has been shaped by speed.

Until the machine age, speed was dependent upon physical effort. Today compressed air, steam, the expanding gases of internal combustion, or electric power furnish the effort; man's energies are devoted to designing the machinery to run safely at the desired speeds.

Speed as it is experienced in its various forms today is the natural consequence of improved machine design. As far as ball and roller bearings are concerned, it stemmed from high altitude aviation and overland (surface) transportation. The grinding machine spindle, the jig borer and the aircraft cabin supercharger rotor are typical examples of mechanisms which today are turning on ball bearings at speeds of from 20,000 to 150,000 R.P.M. With the continued increases in speeds of all sorts during the past twenty years, only the speed of light, and sound (according to air pressure and temperature) seem to be constant today.

Comparative straightway speeds are of interest, for example:

Man has run a mile in 4 minutes and 1.4 seconds.

A horse has run a mile in 1 minute and $34\frac{2}{5}$ seconds.

A train has been run at the rate of 2.12 miles a minute.

An airplane has been flown faster than the speed of sound.

Comparative rotational speeds are equally intriguing, for example:

Textile spindles run up to 30,000 R.P.M.

Woodworking spindles run up to 40,000 R.P.M.

Internal Grinding spindles run up to 100,000 R.P.M.

Aircraft Cabin Superchargers operate in the 25,000 to 35,000 R.P.M. range.

Aircraft refrigeration turbines run at speeds in excess of 100,000 R.P.M.

Ball bearings contributed to the attainment of these high rotational speeds, so desirable in mass production where precision finish is a factor, and in aviation where pressure equalization must be maintained in plane cabins.

THE BENEFITS OF HIGH SPEED

The benefits which result from running spindles at high speed, depend, naturally upon the service involved.

Grinding of metallic surfaces, notably steel, to the high degree of accuracy required for precision machinery, can be controlled more accurately and accomplished more rapidly when the grinding wheel is revolved at very high speed. The jig grinder is well suited for this type of work as it can grind internally, as on ball or roller bearing races, up to a diameter of five inches.

In grinding, the rate of speed depends upon the bore or diameter of the wheel. It is desirable to maintain peripheral speeds of grinding wheels of from 5,000 to 6,000 feet per minute. This would mean that on smaller sizes of bores such as .1250, the required wheel speed would have to be around 160,000 R.P.M. In contrast a 1 inch diameter grinding wheel would revolve around 19,000 R.P.M. To some extent the attainment of such high speeds presents not only a bearing and lubrication problem but also a problem of attaching the wheel to the spindle.

In textile spinning, speed facilitates the spinning of uniform yarns, especially rayons, reducing the time and improving the twist.

High rotated speeds are necessary to obtain high efficiencies in aerodynamic machinery of small size. Necessarily, this implies a rotative speed inversely proportional to a significant linear dimension. In dealing with air-flow rates in the order of 10 pounds per minute at high pressure ratios, it is essential to operate at speeds in the neighborhood of 100,000 R.P.M.

In woodworking smoother cutting, easier operation and high production are obtained when the cutting blade spindle is rotated at comparatively high speed. This applies particularly to the shaper — a type of moulder or planer which is designed for cutting irregular or curved edges along two planes, also to the router. The criterion in woodworking is a surface speed of approximately 12,000 feet per minute. In other words, a woodworking spindle with a 4 inch diameter cutter might be operated at 12,000 R.P.M. or faster.

Constructional features such as cutting circle diameter and the necessity for chip clearance usually limit the number of cutting blades in a cutter to 2, 3 or 4 according to the size of cutter. A high number of knife cuts per minute are necessary for fine finishing. This only is obtainable with high spindle speeds.

BALL BEARINGS WELL SUITED

The ball bearing has proved to be an ideal device for carrying shafts or spindles which must be rotated at very high speeds. Obviously, the turning element must rotate on an axis which is coincident with the axis of its bearing. Any marked deviation or departure from dynamic balance could increase the thrust loads so markedly as to possibly cause the mechanisms to disintegrate, or at least develop wobble or vibration so severe as to defeat the purpose of the design.

The desired degree of precision in the finished spindle or rotor assembly is made possible by finishing the bearing parts in an equally precise manner.

HOW THE LUBRICANT FUNCTIONS

The reason why ball bearings operating at very high speeds and the prevailing loads, must be adequately protected by lubrication, is evidenced by the extent to which stress is involved, as shown in Fig. 1. Ball bearings, unlike plain bearings, do not fail by reason of wear or abrasion — a change occurs in the surface of either or both the balls and races to cause flaking or spalling off of minute particles. Lubrication which keeps the rotating surfaces continually wet with a film of oil, reduces the spot temperature condition which would otherwise lead to metal fatigue. Quite obviously, it is most important to prevent this in a high speed bearing where hundreds of millions of revolutions are required between over-haul periods, or in some cases even between shut-down periods. Oil is the ultimate lubricant regardless of whether the lubricating film is developed by some means for fluid oil dispersing or whether the required oily component for the film is "bled" from the soap base of a grease which is in intimate contact with the rotating parts of the bearings.

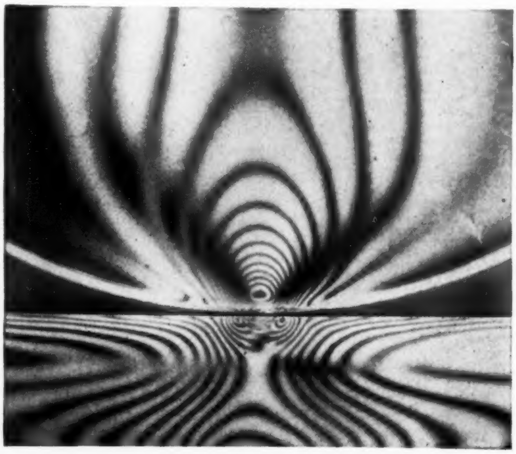
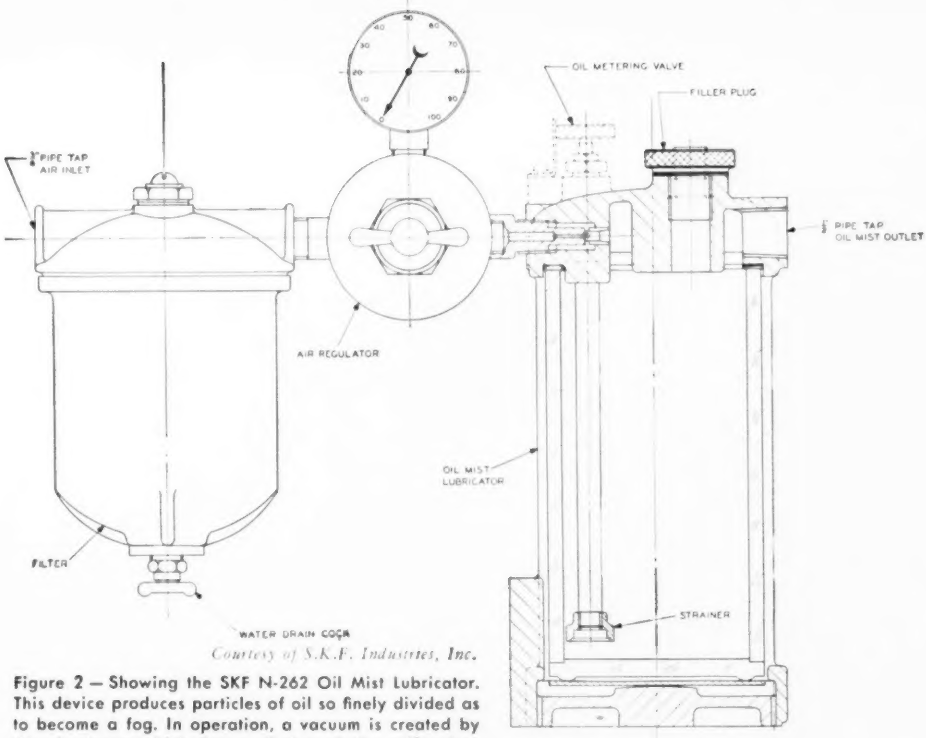


Figure 1 — Showing probable stress distribution in a cross-sectional bakelite model of a ball bearing in compression under polarized light as photographed at the Beacon Laboratories of The Texas Company.

Lubrication at the load carrying surfaces which



Courtesy of S.K.F. Industries, Inc.

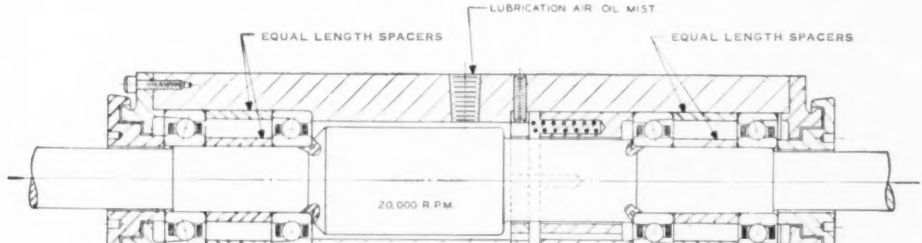
Figure 2 — Showing the SKF N-262 Oil Mist Lubricator. This device produces particles of oil so finely divided as to become a fog. In operation, a vacuum is created by the air stream which draws oil through the orifice into the air stream, thus, forming the so-called fog. The rate of oil consumption can be controlled to as low as a few drops per hour. This fog is so finely divided that it can be distributed to many bearing locations. Also by means of mist producing fittings, this fog can be transformed back to mist or spray or even drops whichever is required on the bearing location. All this is done from a single lubricator.

involve rolling contact, in the opinion of some authorities, is primarily for corrosion prevention. Any sliding velocity which occurs, due to the finite contact ellipse, probably is accompanied by such high contact pressures that oil film action seems unlikely. The major function of the lubricant in a high speed ball bearing would seem to be to minimize friction between the balls and the ball separator.

METHODS OF LUBRICATION

By Means of Oil

Most effectual lubrication of a high speed bearing by means of oil is attained when the volume of oil circulated over the bearing parts is controlled so that just sufficient oil is applied to wet the rolling surfaces. Obviously, an excess of oil such as would



Courtesy of The Barden Corporation.

Figure 3 — Details of a high speed internal grinding spindle showing use of labyrinth type rotating seals.

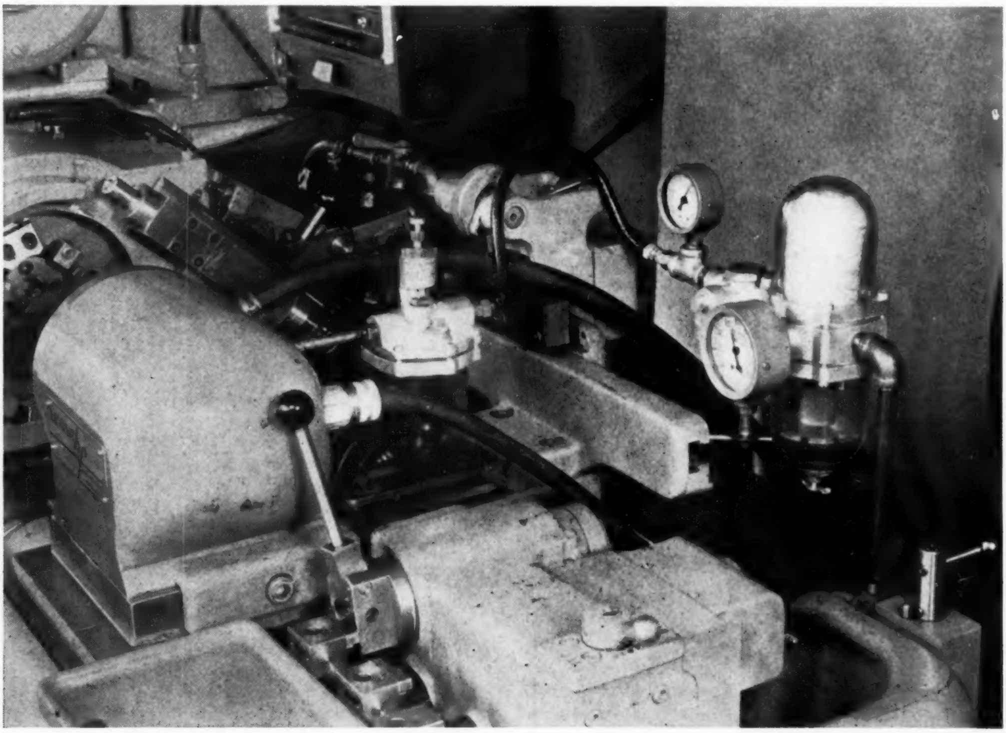
result from flood lubrication might seriously affect the maximum speed of the rotor due to oil churning.

Oil Mist Systems

Oil mist lubrication is not measured lubrication in the true sense of the word although the procedures perfected provide for very accurate control in terms of drops of oil delivered by the oiler or the wick.

lubrication. Since it requires air under a certain amount of pressure, obviously it is most applicable to stationary machines.

Aircraft designers in seeking for a satisfactory method of lubrication for the high speed ball bearings of cabin refrigeration and pressurization equipment, have adapted wick lubrication. The desired oil mist is obtained by submerging one end of a wick in an oil reservoir, the other end being in contact with the high speed rotating shaft surface



Courtesy of C. A. Norgren Co. and Bryant Chucking Grinder Company

Figure 4 — Showing the Norgren lubricator with air filter and regulator as applied to the spindle head of a Bryant chucking grinder. Advocates of this method of lubrication claim:

1. **The air portion of the air-oil fog provides a cooling medium which maintains uniform spindle temperature.**
2. **By permitting the fog to continue flowing for a short time after shutdown, the creation of a partial vacuum within the spindle housing as it cools down is avoided, and harmful grit will not be drawn into the housing.**
3. **The micronic particles of oil penetrate the hard core of air surrounding the rapidly rotating bearing to lubricate it without causing uneven rotation.**
4. **Only new oil is ever carried to the surfaces of the bearing.**
5. **Air pressure slightly above atmospheric is maintained inside of the spindle housing to prevent entrance of foreign matter such as abrasives and coolants.**

The oil mist oiler is a device which injects oil drop-by-drop into a stream of low-pressure air which breaks up the oil into a fine mist. A regulator is provided ahead of the lubricator to accurately control the air pressure being admitted to the lubricator. A high quality filter should also be inserted in the line ahead of the lubricator to provide clean dry air. This type of lubrication assembly is widely used for high speed grinding machinery spindle

(see Fig. 7). At this point a spray of oil is thrown off. Air draft draws this spray or mist into the bearings; no attempt is made to throw the spray directly thereto.

The required air draft is developed by a slinger adjacent to the bearings on the end opposite to the wick contact point. Suitable grooves convert this slinger into an effective air pump. When this device goes into operation at high speed a stable oil mist

fills the entire bearing space and by reason of it contacting all parts of the bearing, it develops a very dependable means of lubrication. No attempt is made to use the oil as a coolant, the desired cooling being developed by conduction through direct contact with the circulated air. This is a highly effective way of cooling when the heat rejection rates of the bearings permit of air and/or conduction cooling. When this is not sufficient, oil cooling jets can be used.

Research has developed that the effective oil pumping capacity of such a wick is surprisingly high. Oil flow rates through a $1/8''$ felt wick in contact with a high speed shaft are as much as 20 cu. cm. per hour by actual observation.

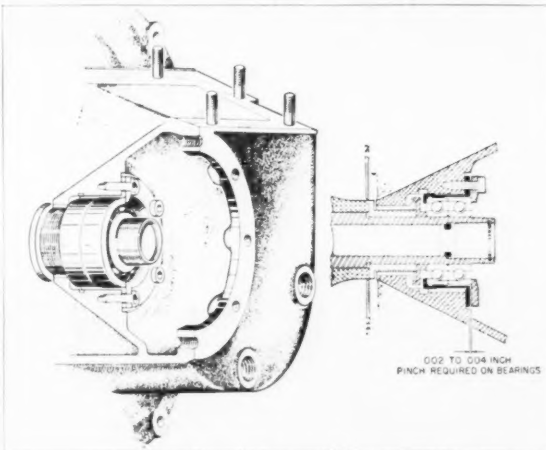


Figure 6 *Courtesy of AiResearch Manufacturing Company*

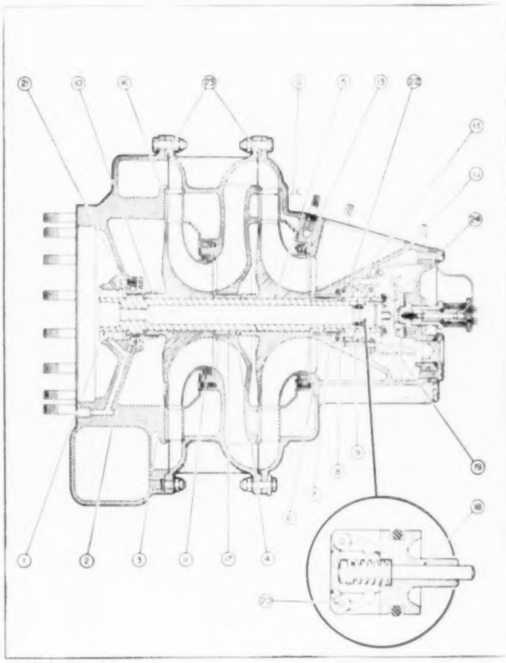


Figure 5

With Oil Slingers

Atomization of oil to some extent is also attained when high speed bearings on horizontal shafts are to be lubricated, by attaching oil slingers to the shafts. As the latter rotate, the slingers which dip into an oil reservoir below, carry a continuous film up into the upper part of the assembly where it is thrown off. An atomizing effect results as oil passes through the bearings. Design of the latter includes apertures of varying size and number which promote the atomizing effect.

Metered Mist Lubrication

Metered mist is another interesting method devised for maintaining dependable oil lubrication of high speed spindle bearings, especially for woodworking machinery. Metered mist lubrication employs the centrifugal force developed by spindle rotation as the power for maintaining the oil feed. Figures 10-13 illustrate the principles of operation. As shown, the hollow spindle serves as a reservoir for the oil. Metering is brought about by centrifugal force pulling the oil through a so-called metering element of predetermined porosity. Metered mist oiling is practicable in any plane.

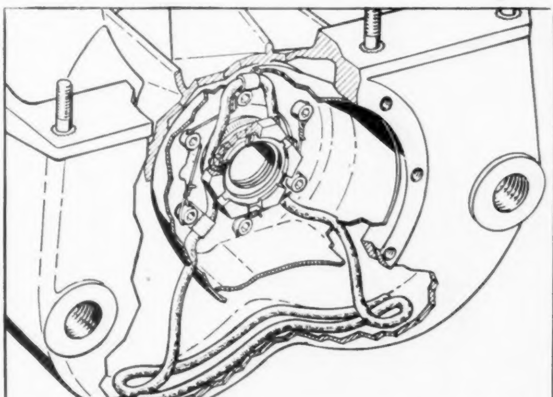
Where it is necessary to provide a quickly available source of oil for high speed motor spindle bearings during the first few seconds of operation a unique priming cartridge has been developed for

Figure 5 — Aircraft cabin air compressor and governor assembly showing at 9 and 14 the location of the bearings with respect to the other parts. (See manufacturers table of limits for identity of the latter.)

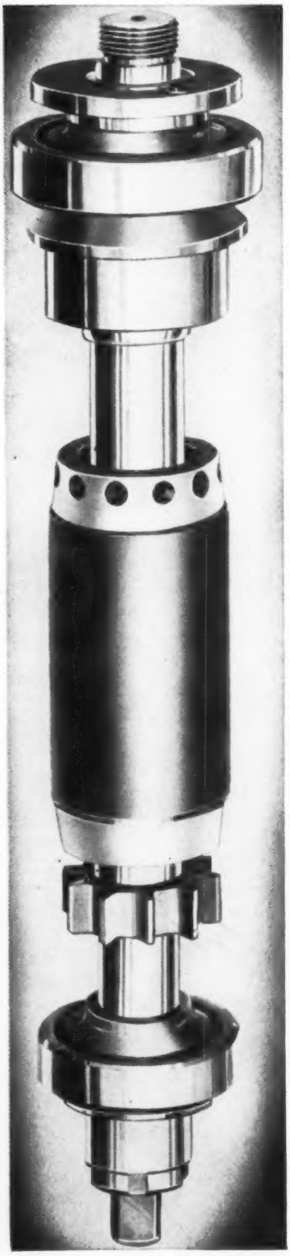
Figure 6 — Compressor ball bearing installation.

Figure 7 — A typical oil wick lubricated installation for a cabin air compressor.

Figure 7



use with a metered mist system (see Fig. 14). This provision for auxiliary lubrication during the start-up period is very desirable where the unit during shut-down may develop enough heat to evaporate the existing oil film from the spindle bearings. High cycle electric motors running for lengthy periods under severe operating conditions when stopped for a few minutes can become so hot as to cause their bearings to run dry until a new oil film is built up, unless means for oil priming is employed. Two or three drops of oil is all that is necessary to develop complete film coverage of each set of bearing elements, and to protect them until centrifugal force and metered mist goes into action to maintain the oil film.



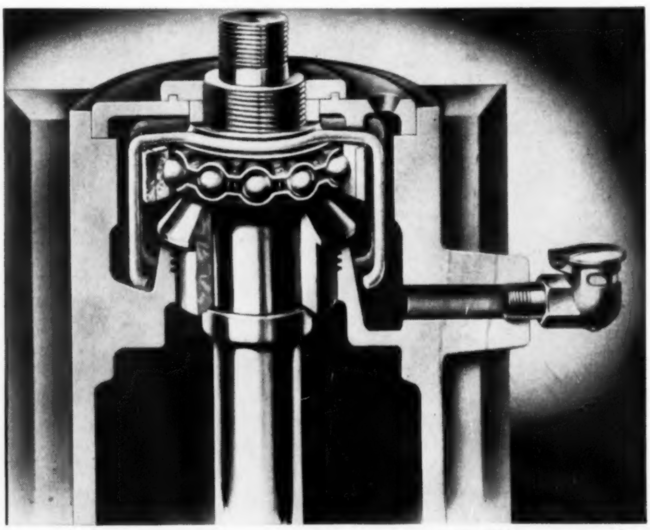
Type of Oil to Use

The oil for an oil mist system should be a comparatively low viscosity mineral (petroleum) oil. (i.e. ranging from 100 to around 350 Seconds Saybolt Universal at 100° F.). Stability is equally as important as the viscosity which only indicates the comparative fluidity, i.e. The highest degree of refinement is necessary for the oil must be resistant to oxidation and gum formation. Conditions are favorable to oxidation due to the finely atomized state of the oil as it is directed to the bearing and the fact that each particle is virtually surrounded by air. Furthermore, the warmer the air the greater the chances of oxidation.

The petroleum chemist has perfected a method of improving the resistance of mineral lubricating oils to oxidation by adding materials which will improve the stability of the oil, thereby imparting resistance to oxidation. Additives also are available which make mineral oils capable of forming rust-resistant films on steels. It is advisable to consider seriously an oil of this type for use in an oil mist system particularly if moisture conditions are extreme and plant machinery such as high speed grinders are involved which are subject to periodic shut-down. Condensation under such conditions could do serious damage to spindle bearings unless the oil is fortified to prevent rust.

High Speed Bearings Carrying Considerable Load

High speed ball bearings in gas turbines and jet propulsion engines carry thrust loads of such magnitude that considerable heat is generated in the bearings due to the coefficient of friction. Obviously this heat must be rejected in order to insure against bearing failure. In the jet propulsion en-



Courtesy of Baxter D. Whitney & Son, Inc.

Figures 8, 9 — Left: A Whitney wood working shaper assembly showing the oversize spindle, heavy duty bearings, fan and oil slingers. Top: The Whitney oil lubrication system showing oil feed to ball bearings by wicks and oil slinger which creates a fine mist of oil in which the bearings run.

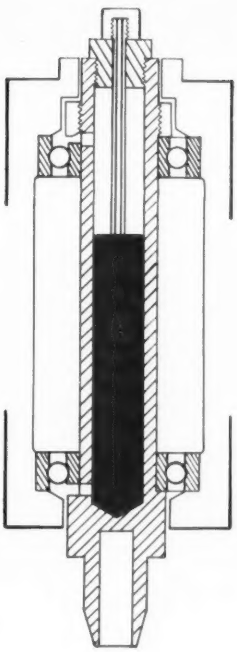


Figure 10

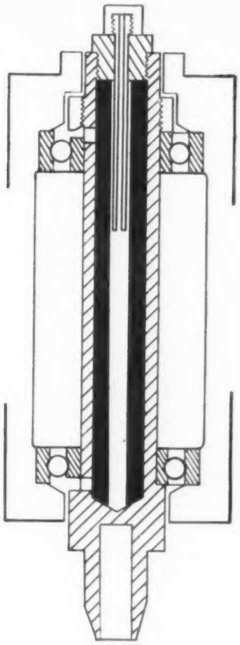


Figure 11

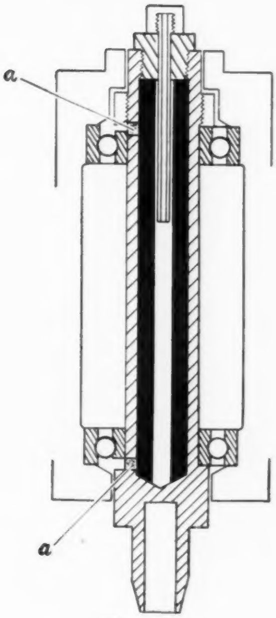


Figure 12

Courtesy of Onsrud Machine Works, Inc.

Showing how metered mist operates.

Figure 10 — The hollow spindle is the oil reservoir. Air is trapped in the upper part by the feed tube, preventing over-filling.

Figure 11 — As the spindle turns, centrifugal force drives the oil against the walls of the reservoir. The air that was trapped forms the core extending upward into the feed tube, thus preventing oil leakage.

Figure 12 — The only points for oil escape are through metering elements (a). Being of predetermined porosity these pass only the desired amount of oil in a given time. They also break up the oil into mist-like particles.

Figure 13 — As the oil leaves the metering elements centrifugal force carries it through spaces (b), into bearing chambers (c).

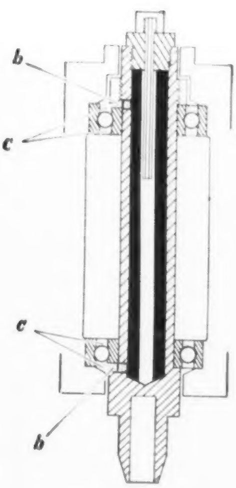


Figure 13

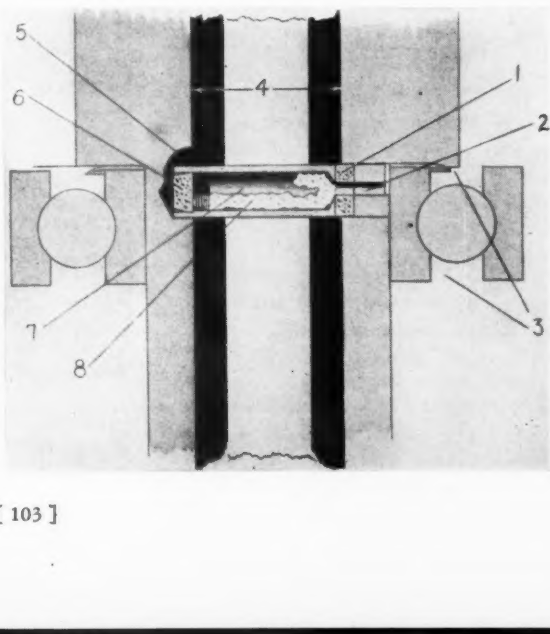
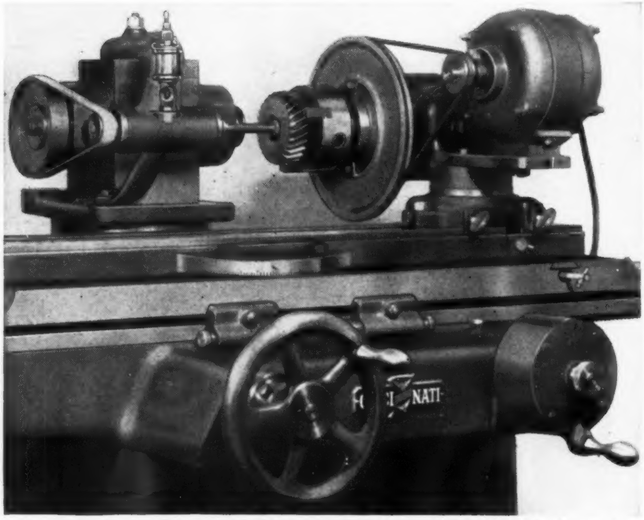


Figure 14 — The Onsrud priming cartridge. (1) Is the porous metering plug; (2) The open feed channel; (3) The bearing chambers; (4) Lubricant on the walls of the reservoir; (5) The wall cutaway and (6) The porous plug. Direction of lubricant through this plug is towards the axis of rotation. (7) Is the priming cartridge. When rotation ceases the priming wick (8) absorbs the lubricant and holds it for recirculation when the spindle again begins to rotate.



Courtesy of Cincinnati Milling and Grinding Machines, Inc.

Figure 15 — Showing the internal grinding attachment on a Cincinnati No. 2 Cutter and Tool Grinder. A 3425 R.P.M. motor with two step sheave mounted in the base of the machine drives the internal attachment spindle at 19590 R.P.M. This spindle runs on precision ball bearings and is lubricated as indicated by a sight feed oiler.

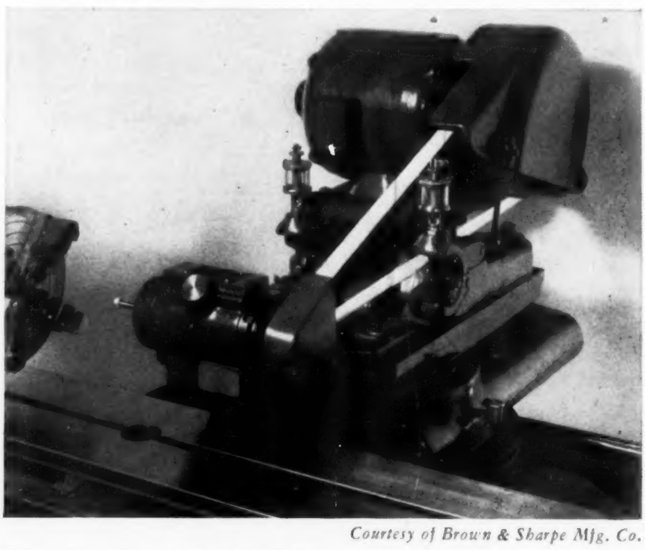
gines and earlier, in turbo superchargers, this was done successfully by lubricating and cooling the bearings simultaneously by injecting solid jets of oil directly into the bearings, the oil striking either on the side of the ball separator or directly onto the balls. Subsequently the oil is thrown off and scavenged out of the bearing housing as rapidly as possible, thereby carrying off the heat and transmitting it to the oil reservoir where it is in turn removed by conduction and radiation. On a bearing having about a 110 mm. bore (4.3307"), as much as three to ten pounds of oil per minute is injected into the bearing. This enables heavy loads to be carried at high speeds. In a recent test at one of the aeronautical engine builders a 7224 size bearing was run under about 12,000 pounds thrust at 8000 R.P.M. Careful observation of temperatures indicated that three pounds of oil per minute were necessary to cool the bearing. Varying the oil flow up to fifteen pounds per minute, did not materially decrease the temperature at flows above five pounds per minute. Where jet lubrication of this nature is used, the primary purpose of the solid jet injection is to carry off heat, since very little of this large volume of oil is needed to lubricate the bearing. It has been found to be more effectual than using large volumes of air at low pressure to carry oil mists through the bearing, depending on the volume of air passing through the bearing to cool it.

GREASE LUBRICATION

Grease packing of ball bearings is very successfully practised where vertical spindles are involved as on high speed jig grinders and electric woodworking shapers, some of the former running as high as 60,000 R.P.M. Two high precision ball bearings carry each spindle. In one very successful design applied to internal grinding service (see Fig. 18), these bearings are grease lubricated from an annular space located above each bearing. At the time of assembly, grease is packed in by hand; and on some, there is no provision for re-lubrication during the running life of the bearing. Other designs provide for pressure grease gun re-lubrication. Lubrication from the original charge of grease is maintained by "bleeding" of the grease just sufficiently to maintain a continuous wetting film of lubricant on the bearing parts. Those who favor grease lubrication claim the advantages, of low cost housings, infrequent lubrication and cleanliness, all of which are important factors in the design of new machinery today.

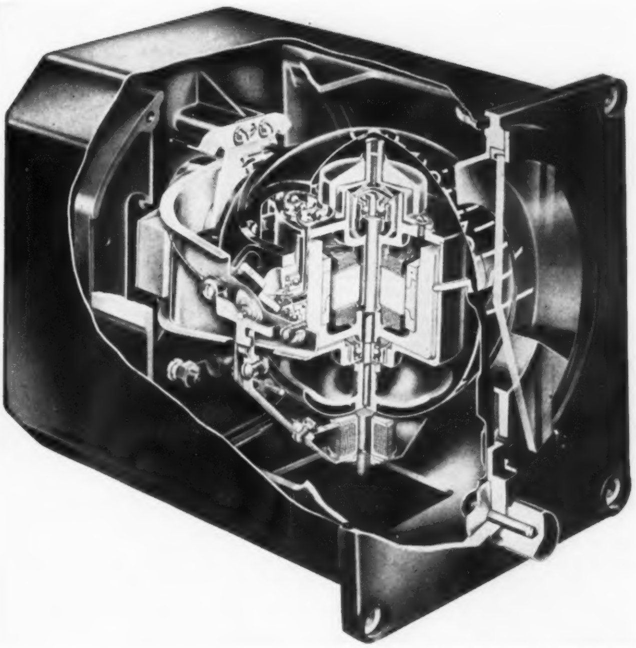
Type of Grease

Certain greases susceptible to shear, bleed oil readily and are considered well-suited for service as outlined above. The presumption is based upon the



Courtesy of Brown & Sharpe Mfg. Co.

Figure 16 — The spindle of the B & S internal grinding fixture is mounted on two super-precision ball bearings, lubricated by oil which is filtered prior to usage.



Courtesy of Sperry Gyroscope Company

Figure 17 — Section of a Sperry Attitude Gyro which operates at approximately 24,000 R.P.M. The rotor bearings are pre-lubricated with grease.

hypothesis that since such greases may contain a number of occluded oil pockets, these latter plus shear-susceptibility tend to maintain a semi-fluid oily condition around the moving parts of the bearing. The fact that the grease is packed into an annular space above the bearing indicates the need for a quick-feeding, medium consistency grease.

Certain laboratory tests indicate that grease allows a lower temperature rise over ambient than does oil. In this regard, the following data is of interest.

Lubricant	*Temperature Rise over ambient, °F.*
Spindle Oil 150 Seconds S.U. Viscosity at 100°F.	92
Grease with 105 Seconds S.U. Viscosity at 100° Mineral Oil	25
Grease with 300 Seconds S.U. Viscosity Mineral Oil at 100°F.	45

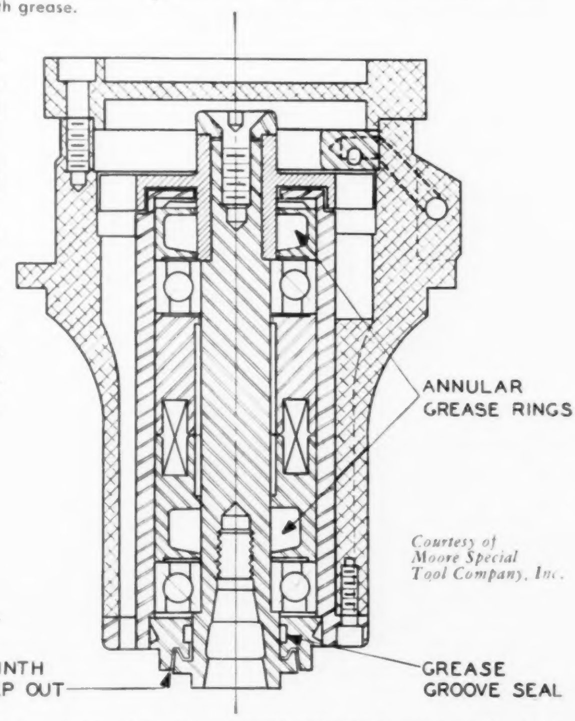
CONTROLLED OIL SUPPLY

Considerable merit is attached to lubrication of high speed ball bearings by oil mist, since the amount of actual oil subject to churning is reduced to a minimum. Churning results in heat generation within the volume of oil being agitated and consequently increased temperature of the bearing as a whole. This is not a serious problem in bearings running as high as 5000 to 10,000 R.P.M. provided the unit is exposed sufficiently to the outside air to permit cooling. Where oil is actually circulated through the bearing, the oil itself functions in part as a coolant.

High speed bearings, however, can be seriously affected by oil churning, the internal friction within causing heat rise and acting as a brake to retard free motion of the bearing elements. This is the primary reason why splash-lubrication is not applicable. Oil mist lubrication, however, prevents these conditions from occurring due to the fact that the relative volume sprayed into contact with the rolling elements is extremely small, in reality only enough to keep the surfaces wet.

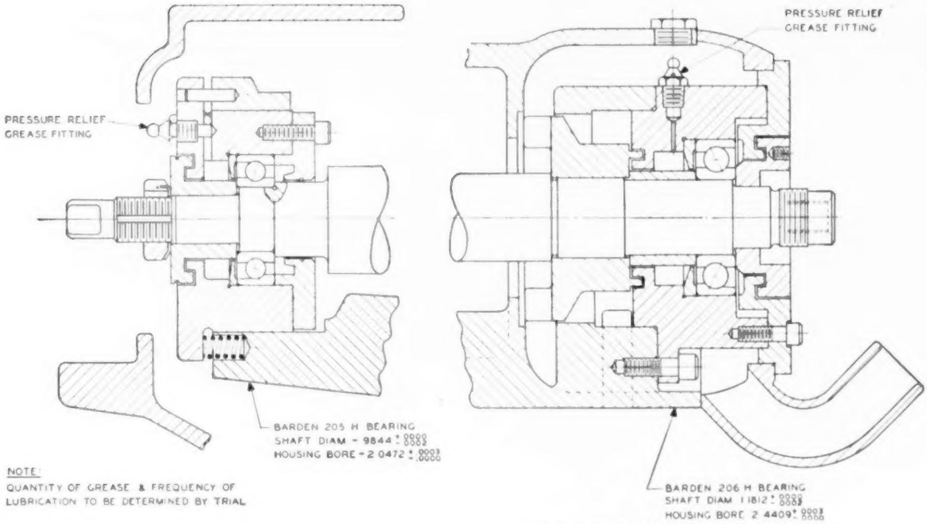
CLEAN AIR MOST IMPORTANT

In any high speed bearing which is provided for oil-mist lubrication the



Courtesy of Moore Special Tool Company, Inc.

Figure 18 — Assembly of the Moore 50,000 R.P.M. high speed grinder head showing annular spaces which serve to retain grease for the upper and lower ball bearings; also the grease seal and labyrinth at the working end of the tool which prevent grinding dust and other non-lubricating material from being drawn up into the bearings.



Courtesy of The Barden Corporation

Figure 19 – Details of a Barden router spindle adapted for grease lubrication.

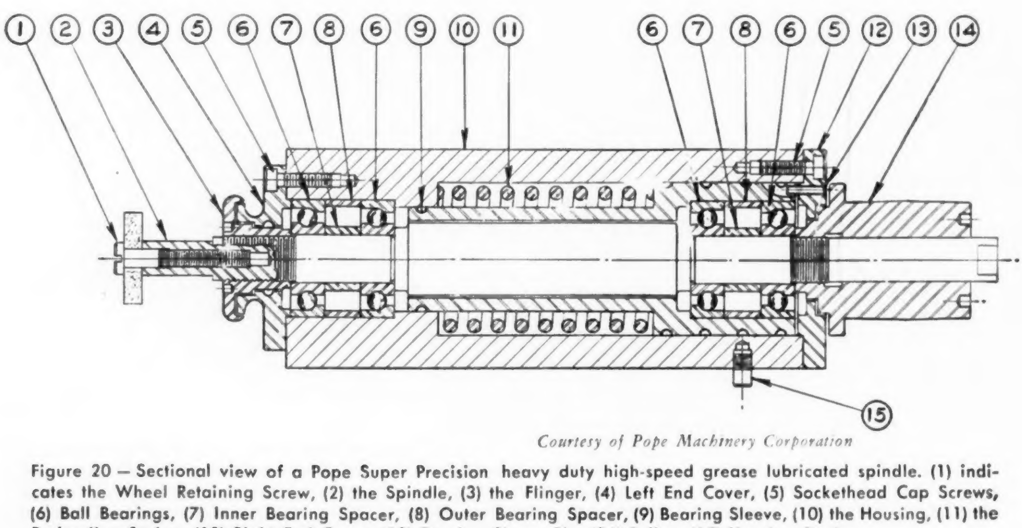
compressed air used to develop this mist via the atomizing device, must be as clean, dry and dust-free as possible. This means that filtered air should be used. The extent to which this can be maintained will depend upon the source of the air, the location of the compressor intake, the air filters used, the frequency with which they are cleaned, the possibility of rust and scale forming in air lines due to condensation when the system is shut down.

Manufacturers of air-oil mist equipment guard against air contamination by supplying a filter, a moisture remover and a pressure regulator so that compressed air from a standard line is properly conditioned before it goes to the spindle.

Minute particles of foreign matter in the air can sufficiently contaminate the oil and penetrate within the bearing to cause noise and rough rolling. If this continues, obviously, the bearing surfaces may become scored, perhaps so severely as to require replacement.

Air-oil mist lubrication has a definite advantage, otherwise, in that the pressure under which it is normally maintained will keep fine grinding dust from being drawn into the bearing.

Precision bearings are built with clearances down as low as 0.0001 inch. Consequently, any foreign particles above this dimension in the lubricant can cause a rough bearing.



Courtesy of Pope Machinery Corporation

Figure 20 – Sectional view of a Pope Super Precision heavy duty high-speed grease lubricated spindle. (1) indicates the Wheel Retaining Screw, (2) the Spindle, (3) the Flinger, (4) Left End Cover, (5) Sockethead Cap Screws, (6) Ball Bearings, (7) Inner Bearing Spacer, (8) Outer Bearing Spacer, (9) Bearing Sleeve, (10) the Housing, (11) the Preloading Spring, (12) Right End Cover, (13) Bearing Sleeve Pin, (14) Pulley, (15) Housing Stud.

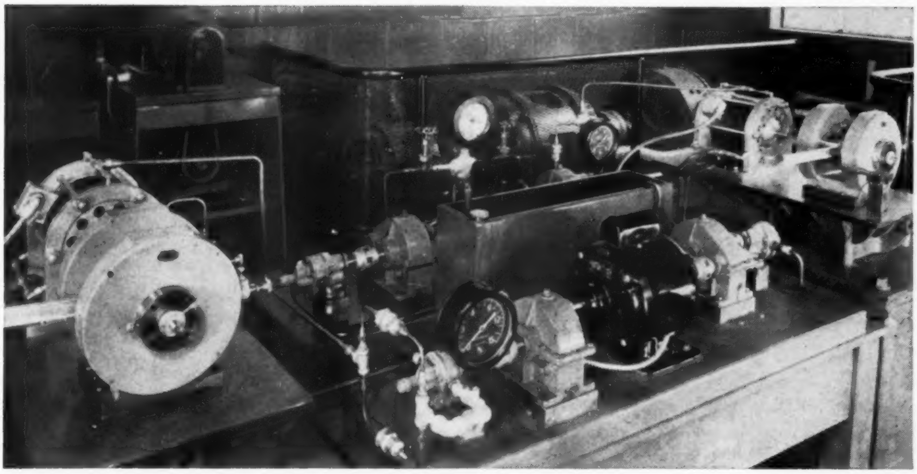


Figure 21

Equipment for high speed grease research at The Beacon Laboratories of The Texas Company.

Above: **Motor Bearing Oil Feed System.** View of auxiliary equipment necessary for operation of high speed electric motors. This includes the motor driven constant volume-constant pressure oil feed pumps which feed oil to the motor bearings and motor driven scavenger pumps to remove the used oil from the bearings and return it to the sump. The oil is filtered and cooled to a specified temperature. Also shown is the water cooling system for the motors.

Below: **High Speed Motor and Grease Test Unit.** Close-up view of the 7 H.P., 36,000 R.P.M., 230 Volt, 600 Cycle motor coupled to the grease test apparatus. The test bearing housing is cradled in two pedestals so as to rotate on anti-friction bearings. The torque developed during rotation is measured by a strain gage and automatically recorded. Bearing and housing temperatures are measured by thermocouples and recorded.

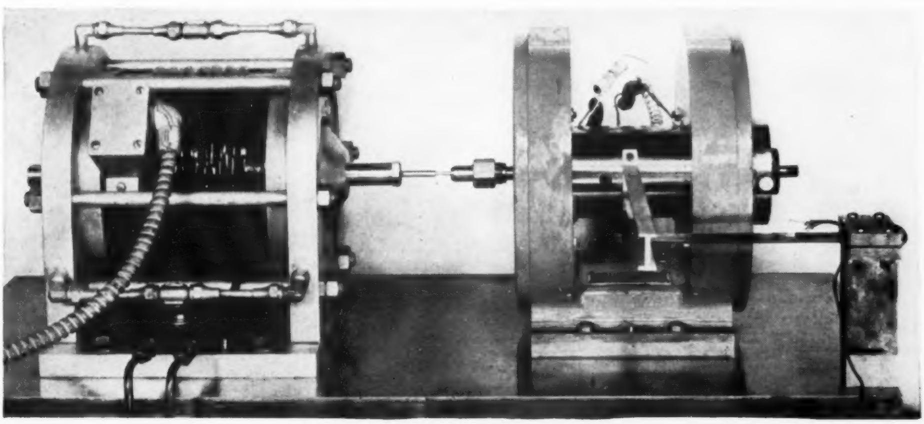


Figure 22

NOISE

Spindles running in ball bearings at very high speeds cause windage, which is one of the reasons for noisy bearings, according to bearing research authorities. Whether or not this noise can be objectionable depends upon the service involved. Obviously, it is desirable to have a quiet bearing by noise testing standards, in the beginning. This is one measure of the suitability of the bearing. In service, it may be different. A grinding spindle or cabin supercharger bearing can produce normal noise without objections. A high speed bearing in submarine service, however, must run as silently as possible to preclude detection of the craft by enemy sonic instruments.

DIRT

Dirt is one of the primary causes of bearing noise. Even the cleanest bearing—by manufacturers' standards—will give up some dirt when soaked in a solvent. Even an ordinarily clean grease contains some foreign particles when studied under the mi-

croscope. On the other hand, these can be reduced to a satisfactory minimum by proper handling in the manufacturing process — a usual procedure among those companies who make a practice of supplying high quality lubricants.

Recently, a sub-committee has been appointed by the National Lubricating Grease Institute and the Annular Bearing Engineers committee* to study methods for determining the number, size and nature of foreign particles in greases and to prepare recommendations concerning interpretation of the data in terms of their practical significance.

The low viscosity mineral petroleum oils so widely used in oil mist systems can be produced virtually dust-free at the refinery. This, however, does not insure that they will remain so when distributed by the oil-mist equipment unless dust-free air is used.

*Institute Spokesman, March, 1948, Page 3.

SEALS AND ENCLOSURES

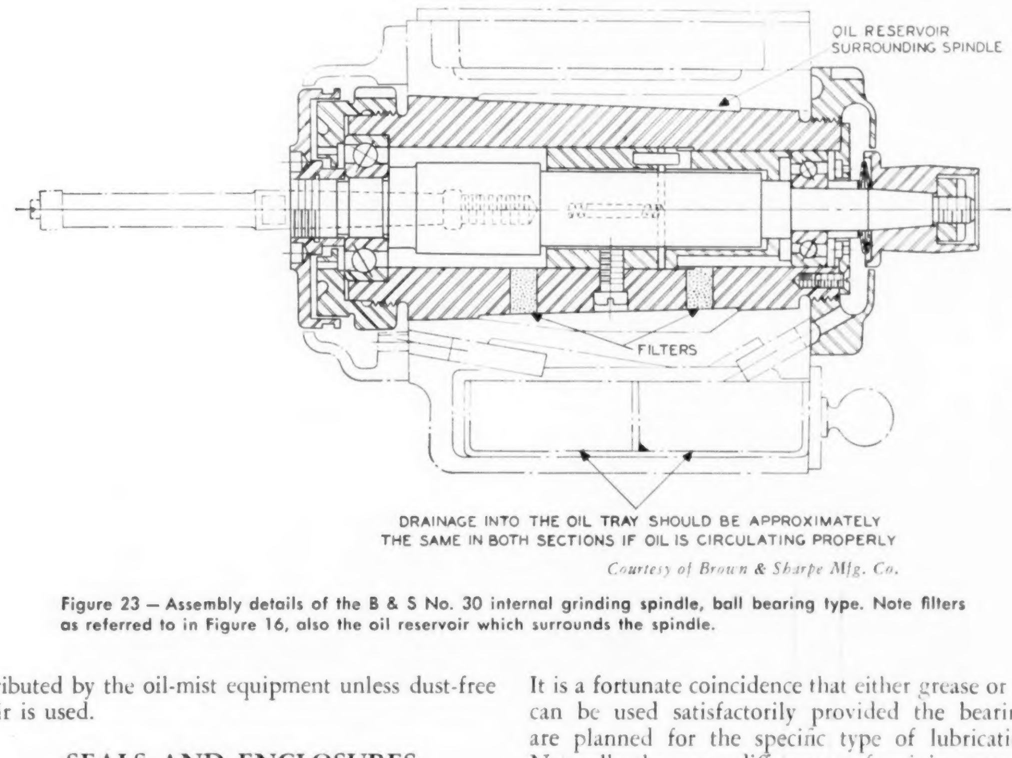
Proper sealing is most important in high speed bearing operation. Labyrinth seals and slingers have been used for this purpose to good advantage. When bearings are adequately protected, against dirt contamination before, during and after installation, their life is prolonged and continued, satisfactory operation is more nearly assured. This is particularly true where grease lubricated bearings are involved. Some spindles may have a tendency to "inhale" after shut-down, others may run with reduced air pressure internally. In dusty atmosphere this may materially affect bearing operation, unless the seals are sufficiently tight and the labyrinths sufficiently intricate to prevent dust being drawn in from the surrounding air.

The problem is not as serious when properly controlled air oil mist systems are used, where a flow of air through the bearing is continually outward under sufficient pressure to keep fine particles of dust from being drawn in.

CONCLUSION

The attention which has been given by the antifriction bearing industry and builders of high speed machinery, to ways and means of insuring positive lubrication is indicative of the importance they attach to this trend towards higher speed operations. It is a fortunate coincidence that either grease or oil can be used satisfactorily provided the bearings are planned for the specific type of lubrication. Naturally there are differences of opinion regarding the relative merits of grease and oil, also the essential characteristics.

This article has been prepared in order to compile a study of the preferred methods of lubrication and to show some of the typical designs. The stimulation of interest from a research point of view, should result in the development of valuable data concerning the most desirable characteristics of lubricants for high speed ball bearings.



Courtesy of Brown & Sharpe Mfg. Co.

Figure 23 — Assembly details of the B & S No. 30 internal grinding spindle, ball bearing type. Note filters as referred to in Figure 16, also the oil reservoir which surrounds the spindle.

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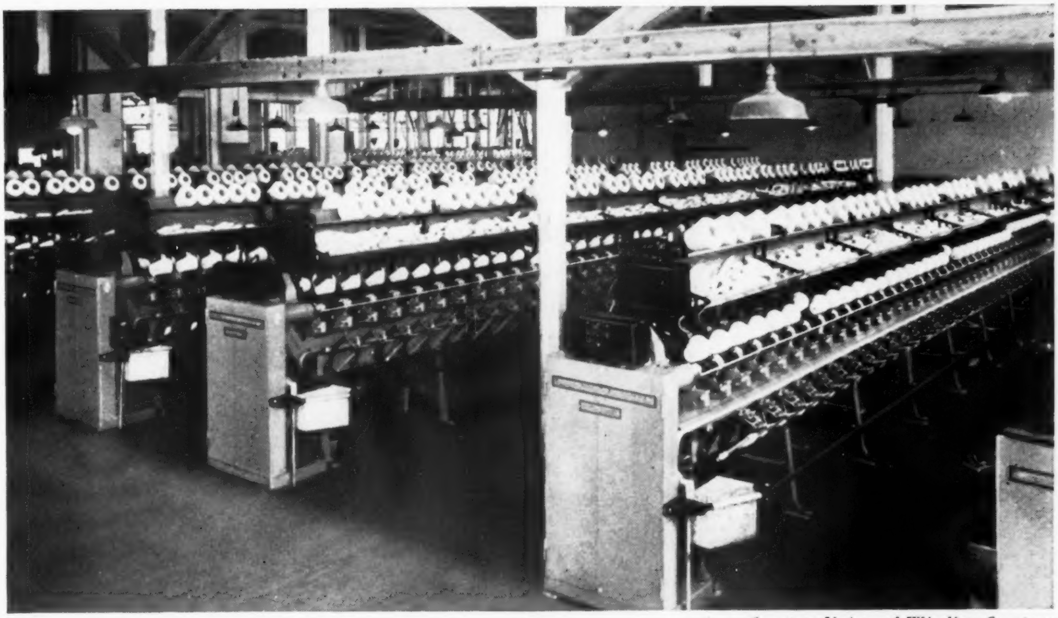

Courtesy Universal Winding Company